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PARASITIC BACTERIA AND THEIR RELATION TO SAPROPHYTES.[1]

BY THEOBALD SMITH.

PARASITES, whether they be animal or vegetable, have certain characters in common which are due to their relation to their host rather than to their own intrinsic organization. I shall endeavor to point out a few of those which may be observed among bacteria parasitic on animals. Since they usually give rise to well-defined diseases, they are also called pathogenic bacteria, or more popularly, disease-germs. Almost all pathogenic forms may be considered true parasites, at the same time all truly parasitic forms have been found pathogenic.

There are certain external regions of the animal body quite uniformly the seat of specific bacteria. They are the skin and alimentary canal. Observations have shown that in the different sections of the digestive tract different bacteria are found. To some of these a digestive function has been attributed, the power of peptonizing albumens, and thus facilitating their absorption. The bacteria inhabiting the mouth are numerous, and some are found quite constantly, such as the well-known *Leptothrix buccalis*. A microcobe has also been found which some years ago was erroneously regarded as identical with the cholera bacillus. The mistake was pointed out by demonstrating its inability to grow upon gelatine, which the cholera germ readily does. I have repeatedly found in my own saliva the same liquefying coccus

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greatly preponderating over other species, although months elapsed between consecutive examinations.

Such bacteria cannot be considered strictly parasitic. It is true that they have adapted themselves to conditions which are now necessary to the continued existence of many of them, yet, if we draw the line at which saprophytic phenomena end and parasitic begin, they are not true parasites. For they do not invade the living tissues to meet the resistance which the living cells interpose, but live upon dead organic matter present upon the skin, in the mouth, and the digestive tract in general.

This adaptation to certain media is common to many micro-organisms. The juice of the grape becomes the habitat of a saccharomyces (*Cerevisæ*) which converts the glucose into alcohol and carbonic dioxide. When this fermentation has ceased the bacterium aceti oxidizes the alcohol into acetic acid. When the medium is too acid the bacterium aceti cannot exercise its fermenting power, and another saccharomyces .(*Mycoderma*) first reduces the acidity of the liquid by oxidation. Examples may be multiplied in illustration of this fact that bacteria as well as fungi select certain media as most favorable to their growth.

It now and then occurs that bacteria not strictly parasitic may prove pathogenic in setting up fermentations and decompositions in the alimentary canal. The substances thereby produced are absorbed, and act as chemical poisons. It seems very probable that our information of digestive derangements will be made more precise and better methods of relief applied when more attention has been bestowed upon the bacteriology of the digestive tract. Under certain conditions the *Leptothrix buccalis*, the most common microbe in the mouth, may become in a sense parasitic. When the enamel of the teeth has been removed by acids formed in the mouth during the fermentation of food, this microbe causes the slow disintegration known as caries by invading the dentinal tubules and the pulp-cavity. Now and then bacteria which carry on a harmless existence in one place may become very virulent in others. A few years ago Dr. Sternberg found that rabbits died within a few days after the injection beneath the skin of some of his saliva. This virulence may last for years. For it is extremely difficult to dislodge a microbe from a place which it finds conducive to its vital activity. Harmless in the human mouth, it is able to multiply in the body of one

of the higher mammals, to act as a true parasite and destroy life. This may explain the occasionally poisonous bites of animals. The sputum in pneumonia has been found equally fatal to rabbits. But here we are confronted with the important but still unsettled question whether the pathogenic microbe in the sputum is not the cause of the pneumonia.

Whether we shall ever find bacteria within the organs, in the blood and lymph-channels of the animal body, as permanent parasites which do no appreciable injury, is very improbable. Many experiments which have been made lead to the conclusion that the animal organism in health is free from bacteria. This is an almost daily experience in the laboratory. Even the excretions, such as urine and milk, are free from bacterial life. Moreover, if there were harmless parasitic forms present, why should we always obtain the same microbe alone from organs affected with the same disease? That bacteria do occasionally penetrate into the closed cavities from the mucous surfaces need not be disputed, but they are quickly destroyed. Large numbers injected directly into the blood have been found greatly reduced in a few hours, and entirely absent after twenty-four hours. To impress this fact more firmly we may picture to ourselves our skin and the entire alimentary canal in contact with myriads of these organisms. A delicate mucous membrane is all that separates them from the vital organs. Yet not a single individual is capable of gaining a permanent foothold within this membrane. This applies only to non-parasitic species, however.

In contrast with this lasting enmity between bacteria and the healthy tissues is the more friendly relation between animal parasites and the latter. Trichinæ and tape-worm cysts enjoy an undisputed repose in the muscular tissue of their host. Some entozoa live in the connective tissue, others infest the blood; they have even been found within the blood-corpuscles of fishes and turtles of apparently normal vitality.

A survey of the various biological properties of those bacteria which have been more carefully studied up to the present does not reveal to us two extreme classes,—those that are capable of a parasitic existence only on the one hand, and those that can only live upon dead organic matter. We actually find bacteria possessing the vicarious power of living, now a parasitic, now a saprophytic existence. The microbes which occasion such dis-

eases as anthrax, typhoid, glanders, cholera, etc., multiply readily in organic infusions in milk, even in drinking-water, for a variable period of time. They grow luxuriantly upon the cut surface of a boiled potato, which is a purely vegetable product. Bacteria of this kind are without doubt closely related to the numberless forms living in the soil and water, and drifted about, in a dried state, with currents of air. Yet they differ in some physiological function, some chemical power, which enables one group to destroy animal life, while the other is itself destroyed as soon as it enters the animal body. There are other parasitic bacteria which are much more fastidious in their choice of a subsistence outside of the body, which shun the boiled potato and require conditions approximating those found in the animal organism. The bacillus of tuberculosis flourishes only on blood-serum at the temperature of the body, and the gonococcus, according to Bumm, seems to prefer human blood to that of the lower animals.

Finally, there are parasitic forms only known to us from a microscopic examination of the tissues which they infest, such as the microbe of leprosy, and perhaps of syphilis. Cultivation upon nutrient substances has not yet succeeded. We must therefore infer that these forms have become so thoroughly adapted to a life in the tissues of the living body that the conditions there prevailing cannot be realized sufficiently in artificial culture to induce multiplication.

These facts explain why many pathogenic bacteria can be cultivated,—grown at will in tubes containing appropriate media; we simply make use of their capacity for living and multiplying upon dead matter, a capacity ancestral in its origin, and suggesting that all pathogenic bacteria were derived by a process of natural selection from the innumerable harmless species everywhere peopling the air, the soil, and the water. How the parasitic nature of these bodies was acquired gives ample scope for speculation, as nothing definite is known. To me it seems most reasonable to suppose that many of the bacteria now known to cause disease acquired certain physiological properties in their natural habitat, possibly in warm climates, which properties accidentally fitted them to live as parasites of the animal organism. These having once been brought together, a new disease, a new scourge was added to the inheritance of animal life. The para-

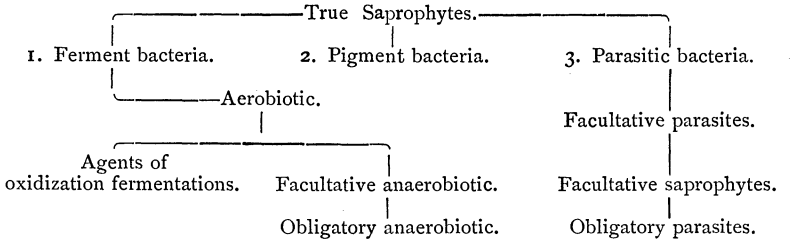
site being subject to all the contingencies which affect other forms of life in nature, it may ingraft itself more and more upon the system, or it may die out in the course of time.

While assuming, without any infringement of known biological laws, that all parasitic bacteria were derived from saprophytic forms, the difference between them is so sharply defined as to make us stand in awe at the tremendous power of the one class when contrasted with the other. Millions of saprophytic bacteria may be introduced under the skin or into the blood-vessels of animals without any marked disturbance. A single pathogenic microbe, by rapid multiplication within the body, may destroy life in a day. The power thus acquired by these minutest and simplest of living organisms is one of fearful effect upon the most highly organized class of animals. It is a war of pigmies against giants, which ends with the destruction of either or both opponents. If the giant be only a rabbit, it is at least a billion times larger than each microbian opponent. If we take the larger animals or man, the relation in size between the microbe and its victim differs but little from that of the earth and the meteorite falling upon its surface.

The derivation of pathogenic from harmless saprophytes is well suggested by three organisms,—those causing Asiatic cholera and typhoid in man and so-called cholera among swine. These organisms thrive very well upon various media, indicating that they are not necessarily limited to the living body as a habitat. But the remarkable feature which they have in common is their power of spontaneous movement in liquids. During their parasitic life this function does not appear to be of any service whatever. The bacteria of cholera are restricted to the small intestine, where they multiply with enormous rapidity. Those of the other diseases mentioned are not limited to the intestines, but may be found growing in the blood-vessels of various organs in the form of dense colonies or plugs. The motility must be regarded as a feature of their saprophytic life which they would lose if a strictly parasitic habit were finally adopted. An illustration of a somewhat different nature is furnished by the *Anthrax bacillus*, the first disease-germ thoroughly studied, which produces such a rapidly fatal malady in many of the domesticated animals and in man. According to Koch, it is an inhabitant of certain low, marshy regions, where it goes through its cycle of growth without enter-

ing the animal body. In fact, it cannot complete this cycle within the body, for that most important stage—spore formation—only takes place on exposure to the air, so that bacilli within the dead body, if immediately buried, do not form spores. These facts illustrate clearly the preponderance of a saprophytic life in this very virulent organism.

To indicate graphically the probable phylogenesis of parasitic bacteria, Hüppe has constructed the following table, according to De Bary:



The term facultative parasites signifies that the bacteria included in the class are capable of living as parasites or of passing through certain stages of their development as parasites. Facultative saprophytes are such parasites which may live as saprophytes either during the whole or a part of their life-cycle.

If for a moment we look more carefully at the parasitic life of bacteria, a number of interesting facts and problems appear. First of all each microbe produces definitely characterized symptoms and lesions which are grouped together as a specific disease. According to the abode which the microbes choose in the animal body, these symptoms and lesions will vary within wide limits. Some species multiply within the capillary system of the various organs, some are confined to the lymphatics, while others produce suppuration in the connective tissue by attracting an army of leucocytes to oppose them. A few are constantly found within leucocytes themselves. Some bacterial diseases are limited to special organs or tissues. It may be the lungs or the spleen, the skin or the mucous membrane of the intestine which becomes the seat of attack, and to which the disease remains restricted. In the various situations minor modifications in disposition and grouping give rise to diseases of quite different character. Bacteria growing in dense plugs in the capillaries produce in-

juries and changes different from those which arise when they are loosely scattered.

It is a curious fact that those bacteria which are strictly parasitic and which have not yet been cultivated in nutritive media, or only with considerable difficulty, cause diseases which are very slow in their progress, often lasting for years and frequently checked and cured. Tuberculosis, syphilis, and leprosy are illustrations of this fact. On the other hand, the diseases which are produced by bacteria that thrive in artificial media are usually quite rapid in their course. The conflict in the latter case is much fiercer and more quickly decided. In other words, the bacteria are more virulent. The better adapted the parasite becomes, the more compatible will it be with the host and the less capable of carrying on an independent existence. It is for the interest of the more strictly parasitic forms that their host live as long as possible. This is not necessarily so with those species whose life in nature may continue more or less independent of a parasitic existence.

The more perfect parasitic bacteria, manifesting their presence in very slowly progressive maladies, usually reside within the protoplasm of the cells, where the feeble irritation leads to a hypertrophy and then to a gradual destruction of the cell itself. The bacteria are probably taken up in the same way in which the amœba takes in solid particles. The cell endeavors to destroy them in this way, but their persistence within the cell-protoplasm indicates that the struggle has resulted in the victory of the parasite, which even finds the battle-ground a convenient place of abode. There are one or two rapid diseases, such as mouse septicæmia, in which this intra-cellular habitat of the microbes is always observed.

Another interesting feature which they share with entozoa is their limitation to certain species of animals. Some are peculiar to one species, others may thrive upon several. This susceptibility of certain animals to definite pathogenic germs is so constant a phenomenon that it has now become an indispensable means in the diagnosis and differentiation of bacteria, and in conducting investigations upon obscure points in the life-history which are of direct practical value. In other words, the smaller animals are to the pathologist what chemical reagents are to the chemist.

I have already stated that there are many entozoa, inhabiting the tissues of their host, which do but little harm, and which may measure their parasitic existence by years, while a few, such as *Trichina spiralis*, are now and then fatal. Corresponding with these gradations in destructive effect there are similar gradations of virulence among bacteria. Some produce only local disturbances; they are speedily destroyed and eliminated. Among these are the microbes causing suppuration. Others destroy organs and tissues very gradually, and are indirectly fatal by exhausting the vital energies or breaking down some organ necessary functionally to the processes of life. Among these may be mentioned more particularly the tubercle bacillus. Still others may cause death from within a few hours to weeks after their invasion. These include the microbes of septicæmia, cholera, typhoid fever. In general, however, the tendency of bacterial parasites is eminently destructive. The chemical poisons formed during their growth irritate and finally destroy the animal cell. If we pass from a consideration of the biology of these micro-organisms to the diseases of which they are the cause, a broad field of interesting facts lies before us, as instructive and suggestive to the biologist and the student of nature as to the pathologist and the practical physician. I can, however, merely glean a few facts which may serve to illustrate the relation of epidemics to the life-history of bacteria.

There is a certain group of diseases called miasmatic, because the poison seems to come from the air and the soil. With the light shed upon this subject in recent years, the micro-organisms, presumably the cause, live in the soil as their natural habitat. This class would include all strictly endemic diseases, since they cannot be carried at will to localities free from them. The cause, residing in the soil, must have certain conditions necessary to its life, and unless these are found in new localities the disease will not take root. Though malaria is reaching out into new territory, we have never yet heard of a quarantine against its progress.

Another group includes maladies only transmitted from one subject to another. They are strictly contagious diseases, corresponding to the strictly parasitic bacteria, which cannot multiply outside of the animal body.

A third group, intermediate between these extremes, possesses, in a way, the characteristics of both. The micro-organisms may

live both as parasites and saprophytes; and being capable of multiplying wherever the proper pabulum exists, the possibility of rapid diffusion, and hence of great epidemics, is readily conceivable. It is believed by some that for most of such germs a sojourn in the soil is a necessary preparation for the parasitic stage. Pettenkofer regards cholera and typhoid not contagious, but insists that the germs must first undergo some unknown changes in the soil before they again become capable of inducing disease. Hence the spread of epidemics depends as much upon certain external conditions as upon the presence of the agents themselves. This is controverted ground, however, and most authorities to-day are inclined to consider the air, the soil, and water as simple vehicles for the spread of disease.

There still remain many obscure problems concerning the movement of epidemics, but their solution does not seem so far away, as a very firm foundation has been laid for future observations. This has been constructed from the life-history of micro-organisms. The application of the principles and fundamental facts of biology to the elucidation of the causes of disease and its prevention is once more brilliantly vindicated. Disease is no longer the mysterious, personified entity of the past. It has been brought within the domain of laws which govern all life upon the earth.

ON SOME POPULAR ERRORS IN REGARD TO THE ESKIMOS.

BY JOHN MURDOCH.

ONE is often surprised, on taking up a popular treatise on anthropology, to find the number of erroneous beliefs concerning a race of people about whom so much has been written as about the Eskimos, which have been quoted by author after author without question, until they have come to be accepted by the world of readers as matters of established fact. Most of these errors are due to the fact that many of the earlier authors, even when themselves explorers who correctly recorded the facts they observed, hastily accepted the conclusion that isolated peculiarities were characteristic of the race as a whole, as if, for